

# **Sensitivity of Satellite Altimetry Data Assimilation on a Naval Anti-Submarine Warfare Weapon System**

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Past Thesis: Michael Perry ENS, USNR

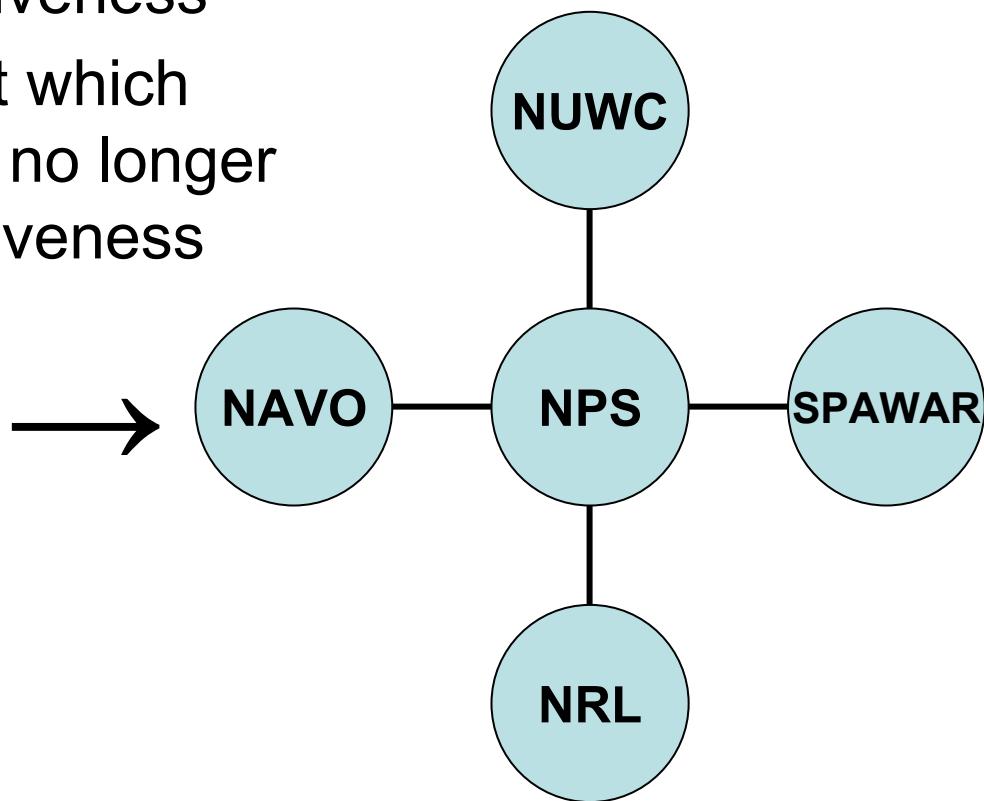
Collaborator: David Cwalina

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- Purpose and Objective
- Past and Present Thesis Summaries
- MODAS Introduction & Field Comparison
- WAPP Introduction & Processing
- Analysis of Output
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# Purpose

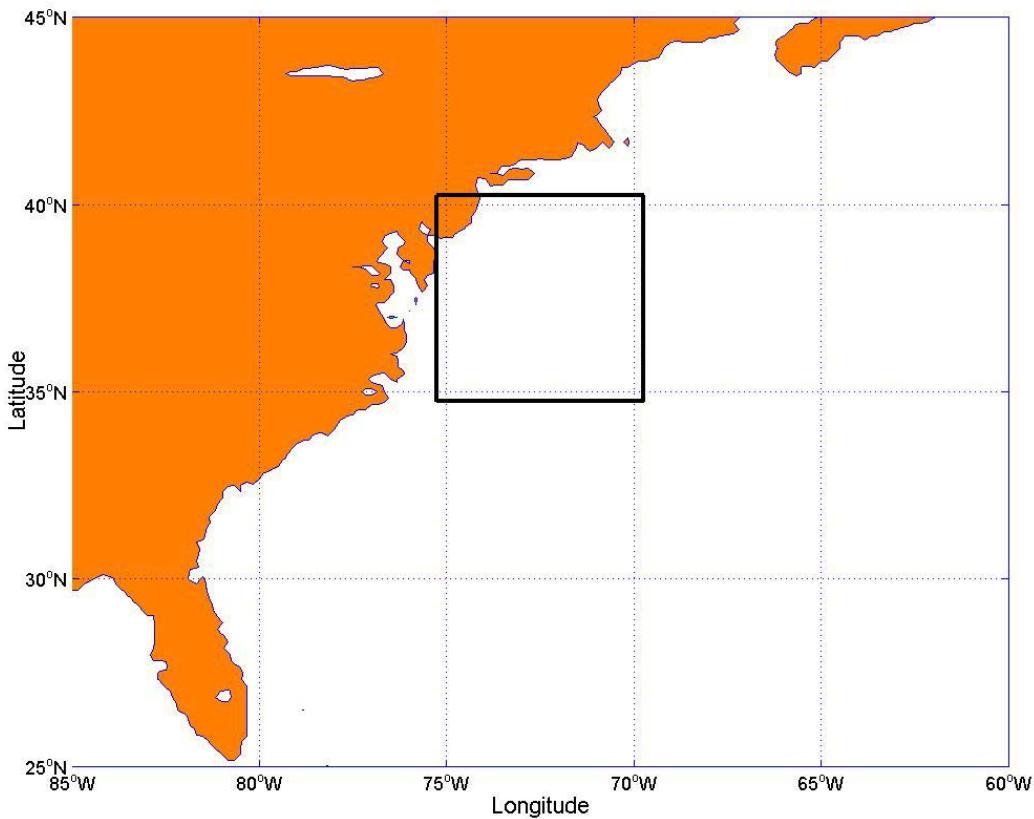
- To define Navy altimeter requirements as a minimum number of satellite altimeters necessary to ensure maximum weapon effectiveness
- To determine the point at which additional altimeter input no longer increases weapon effectiveness
- Collaboration elements →



# Objective

- Identify the sensitivity of satellite altimetry data assimilation on weapon presets
  - To determine if further work should be done to assess the value of the altimetry data

# Past Thesis



- Michael Perry, June 2003
- GDEM vs MODAS with 3 altimeters
  - March 15, 2001
  - 117 vs 1633 profiles
  - 35.0-40.0N
  - 70.0-75.0W
- Area coverage is an effective metric for comparing weapon presets

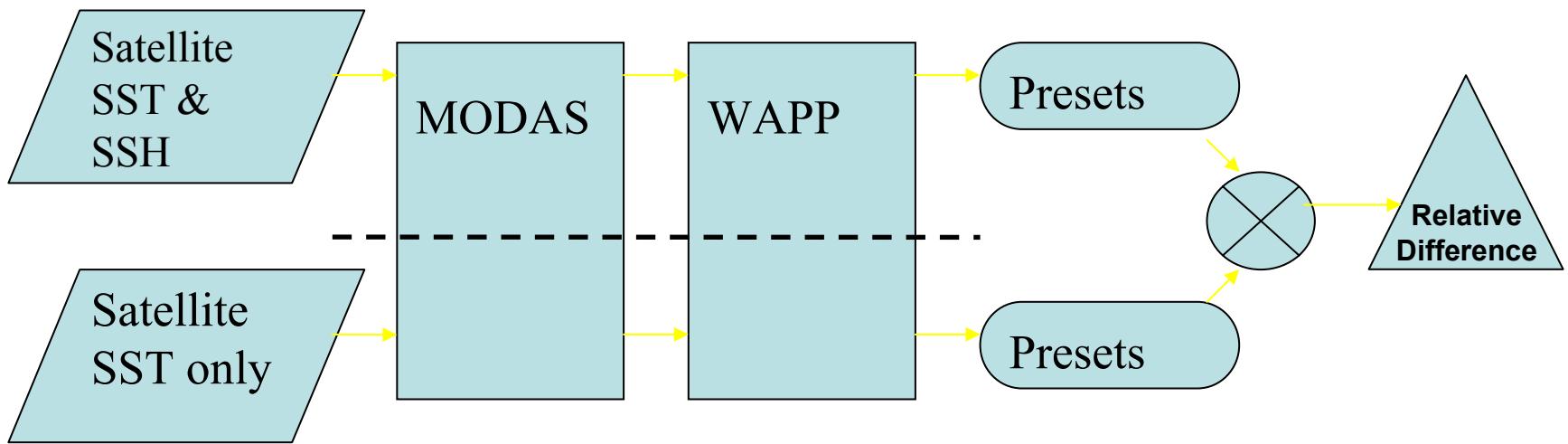
# Future Projects Recommended by Past Thesis

- More Extensive Data Set
  - Observe changes over time and for different locations
  - Examine areas of strong thermal or salinity contrast
- Altimeter Investigation
  - Vary the number of altimeters and observe the effect on area coverage
  - Determine optimal number of altimeters required

# Current Thesis

- Compared WAPP output using 2 MODAS fields
- Looked at 3 geographic areas at 2 different times of year
- Used relative difference in area coverage for quantifying the effect on weapon presets

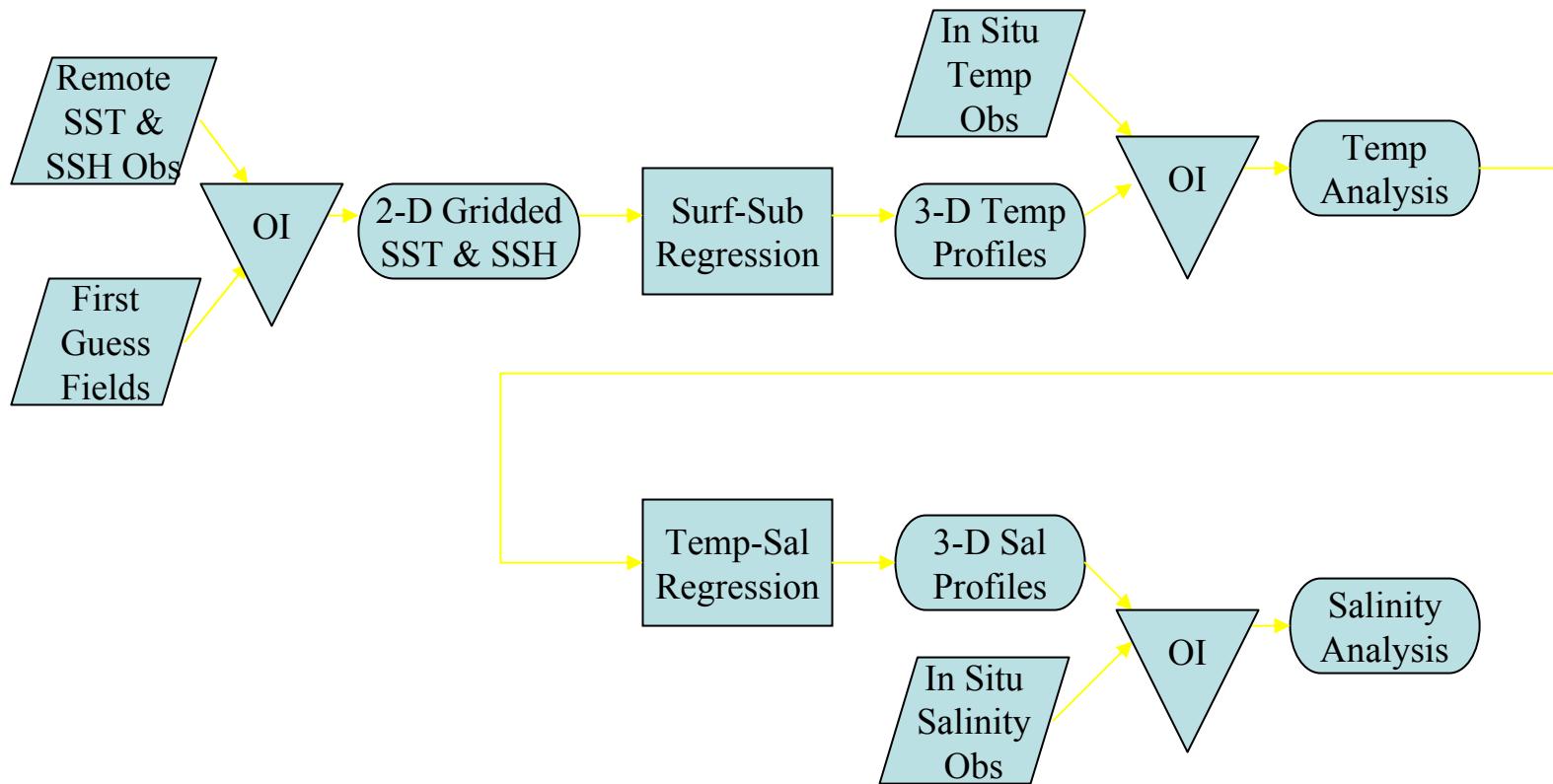
# Process Flowchart



# **Modular Ocean Data Assimilation System (MODAS)**

- Analysis tool only, predictive capability using NCOM
- Dynamic climatology uses optimum interpolation to ingest
  - SSH and SST from satellites
  - In situ measurements (XBTs, CTDs)
- Produces
  - 3-D Temp grid up to 1/8 degree resolution using surface-subsurface regressions
  - 3-D Sal grid using T-S regressions
  - Derives density, sound speed, mixed layer depth, etc.

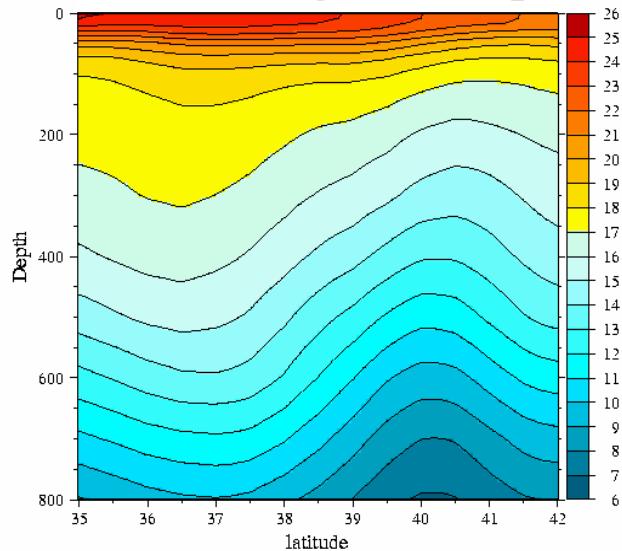
# MODAS Flowchart



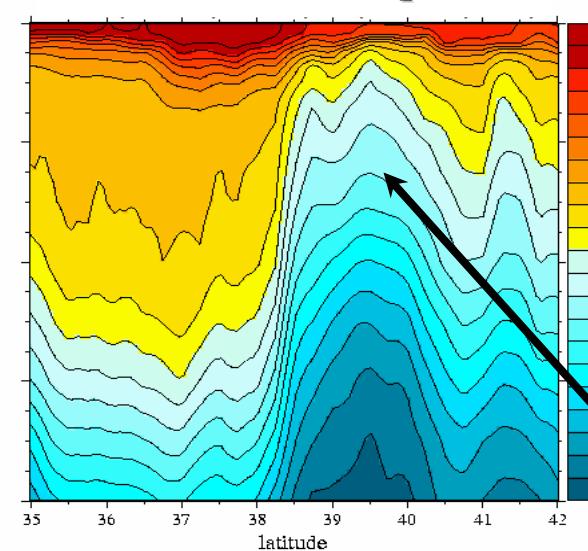
# MODAS

MODAS results

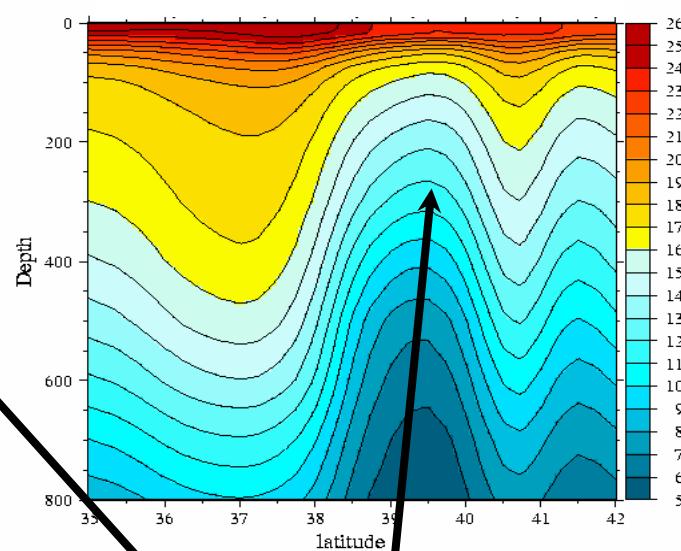
Climatological Temp



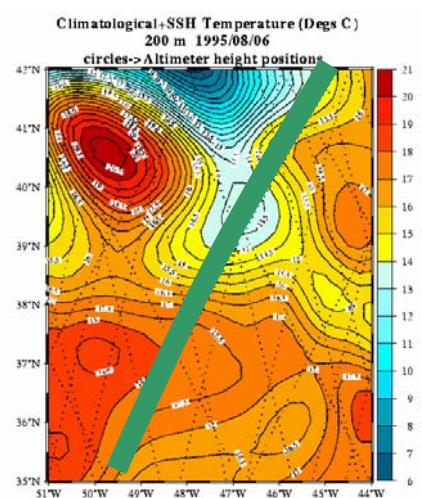
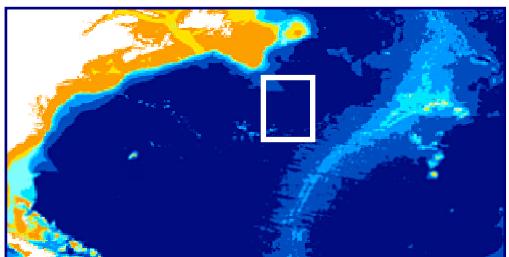
AXBT Temp



SSH + SST + Clim



6-Aug-1995



Cold core eddy

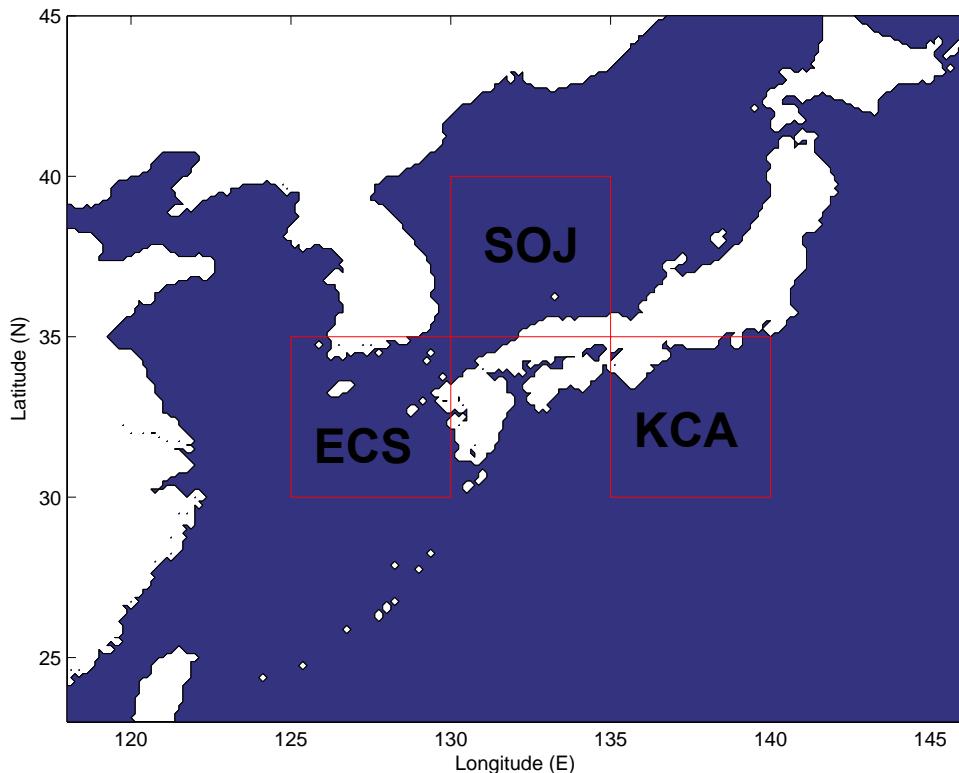
MODAS  
Temperature  
at 200m

# MODAS Fields

- 2 daily global MODAS fields
  - June 30, 2001
  - October 10, 2001
- 2 versions
  - one with assimilated data from 3 altimeters (TOPEX, GFO, and ERS-2)
  - one without altimeter data assimilated

# Areas of Investigation

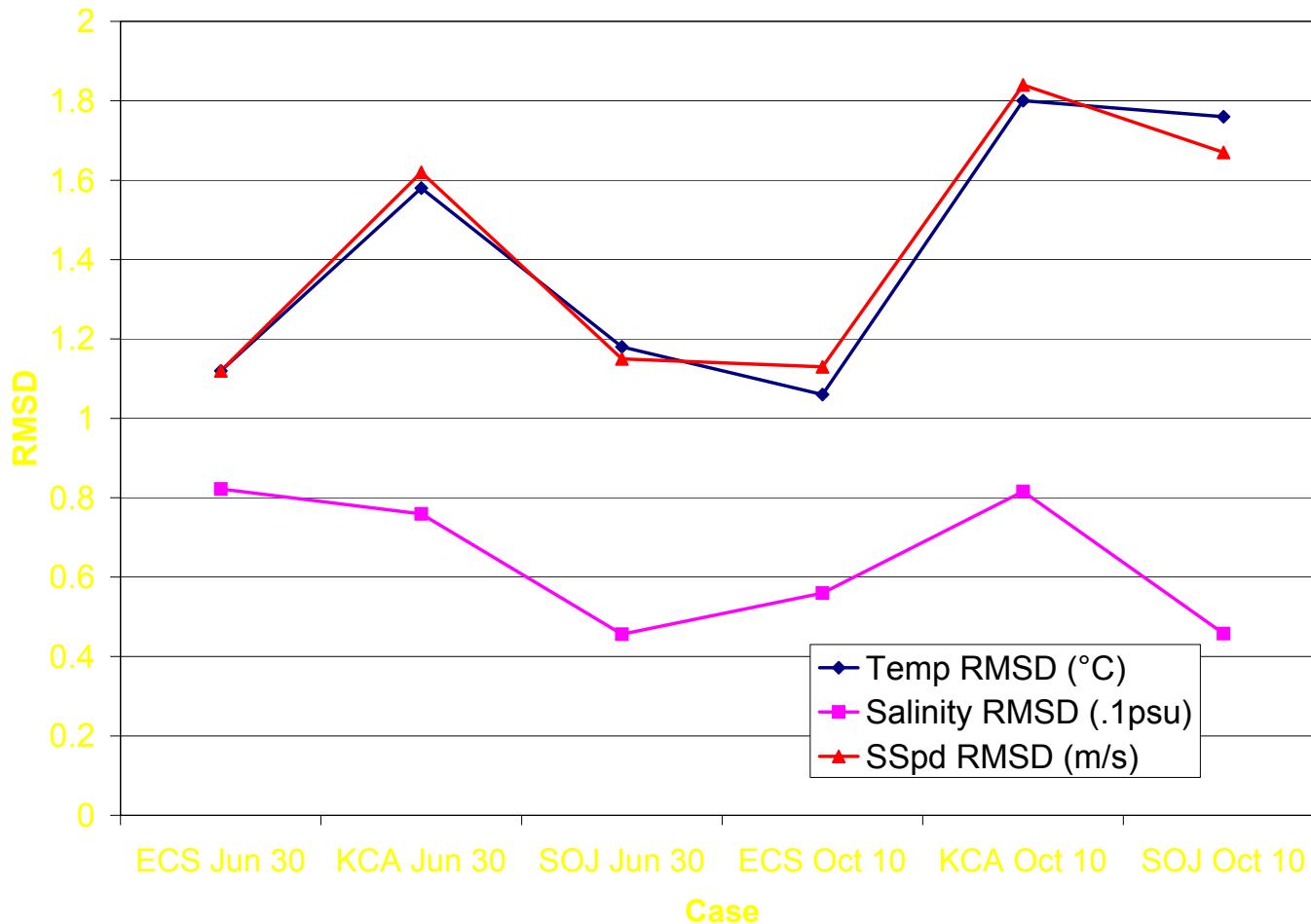
- 3 geographic areas (5 X 5 degree boxes)
  - Sea of Japan (SOJ)  
35-40N, 130-135E
  - East China Sea (ECS)  
30-35N, 125-130E
  - Kuroshio Current Area (KCA)  
30-35N, 135-140E
- 6 cases (2 days X 3 areas)
- Resulting input data set
  - 4,379 pairs of water column profiles for each day



# Comparison of MODAS Fields

- Compared fields at each horizontal grid point and depth ( $\Delta X_i$ )
- Computed volumetric
  - Mean  $\Delta X_i$  (bias)
  - $\Delta X_i$  standard deviation
  - RMSD =
  - Created scatter plots, histograms and horizontally averaged bias and RMSD vertical profiles

# MODAS Volume RMSDs



# Weapon Acoustic Preset Program (WAPP)

- Naval Undersea Warfare Center, Division Newport
- Generates Mk 48 torpedo acoustic presets
- Visualize predicted torpedo performance

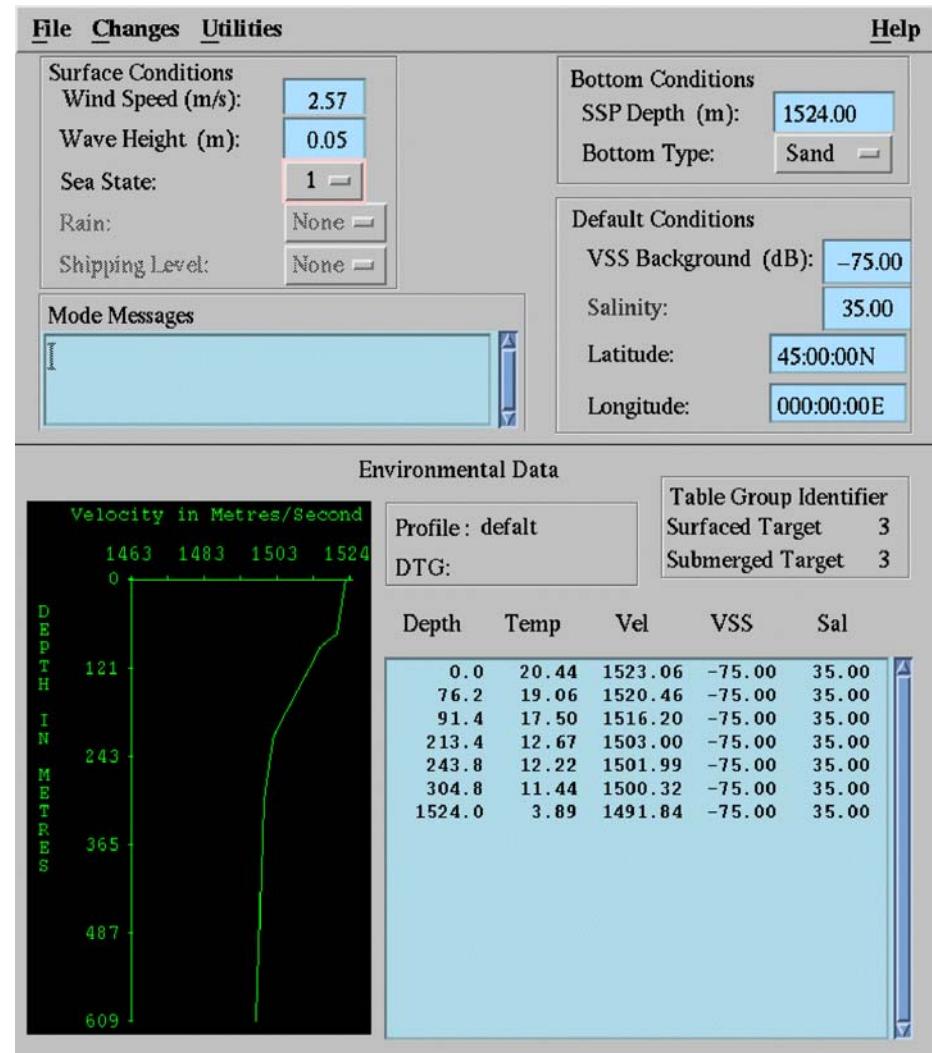


# WAPP Composition

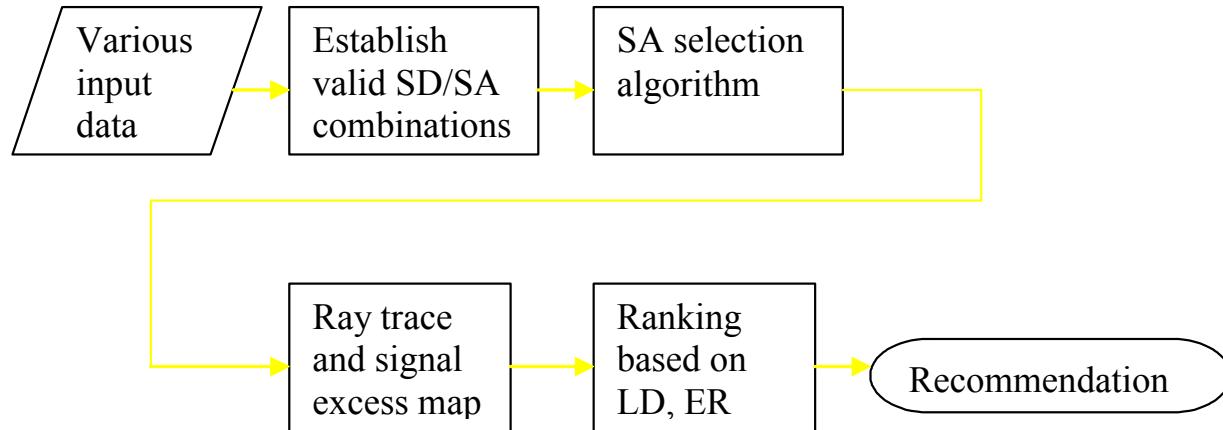
- Graphical user interface (GUI)
  - Entering of environmental, tactical, target, and weapon data
- Computational engine
  - Generating acoustic performance predictions
- Output
  - A ranked listset
  - Acoustic ray traces
  - Signal excess maps

# Environmental Data Entry (EDE) Window

- Water column parameters
  - T, S, Sound Spd, VSS
- Surface conditions
  - WS, WH, Sea State
- Bottom conditions
  - Depth, type



# Presetting Process



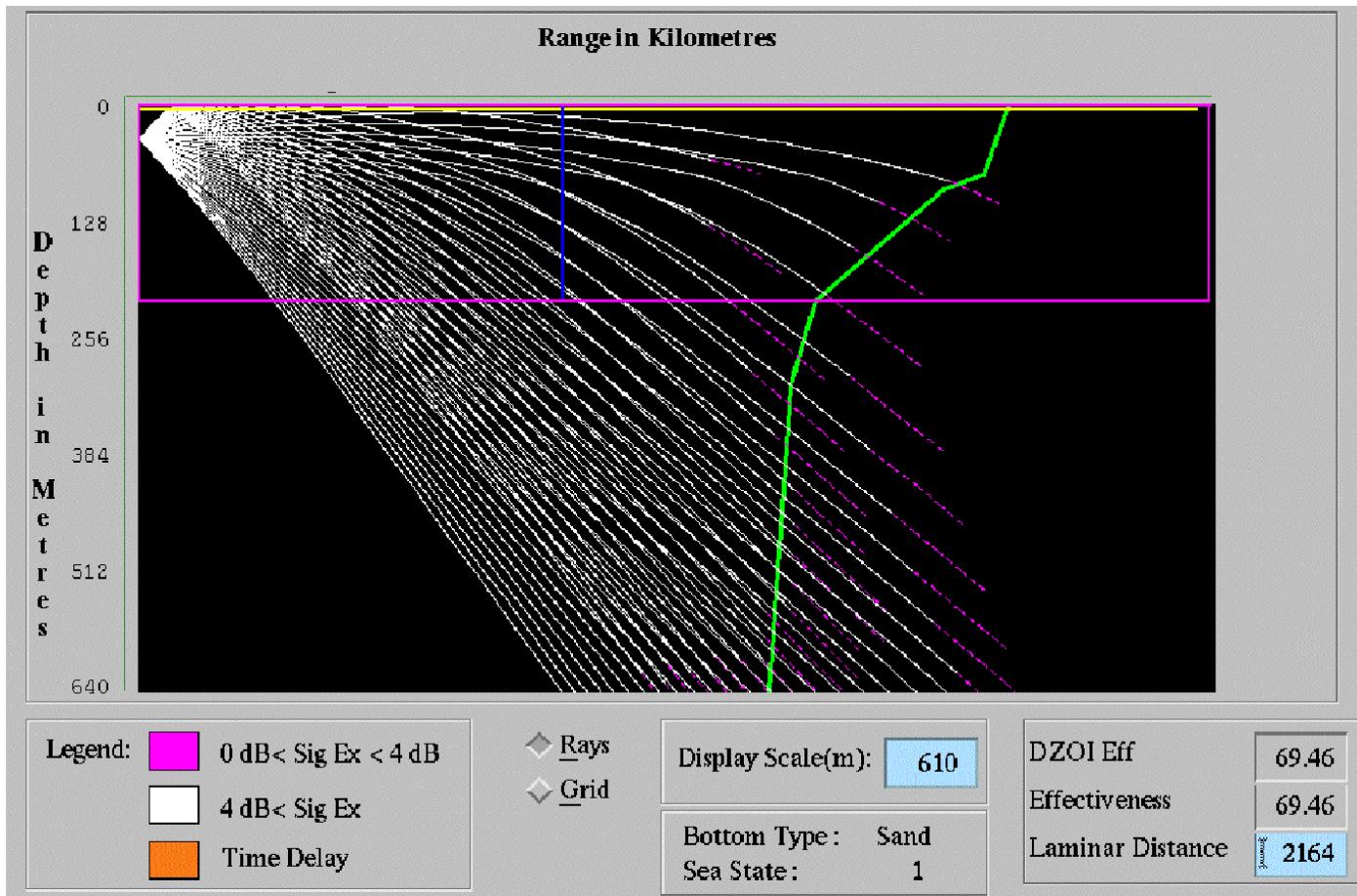
- SA selection algorithm
  - Identifies optimal pitch angle for each search depth
- Ray trace
  - Range-independent ray propagation model accounts for spreading, refraction, volume absorption, boundary interactions
  - Fan of rays bound torpedo beam pattern
- Signal excess map
  - Uses monostatic, active sonar equation (reverb limited):
$$SL - 2TL + TS - RL - DT = SE$$

# WAPP Ranked Listset

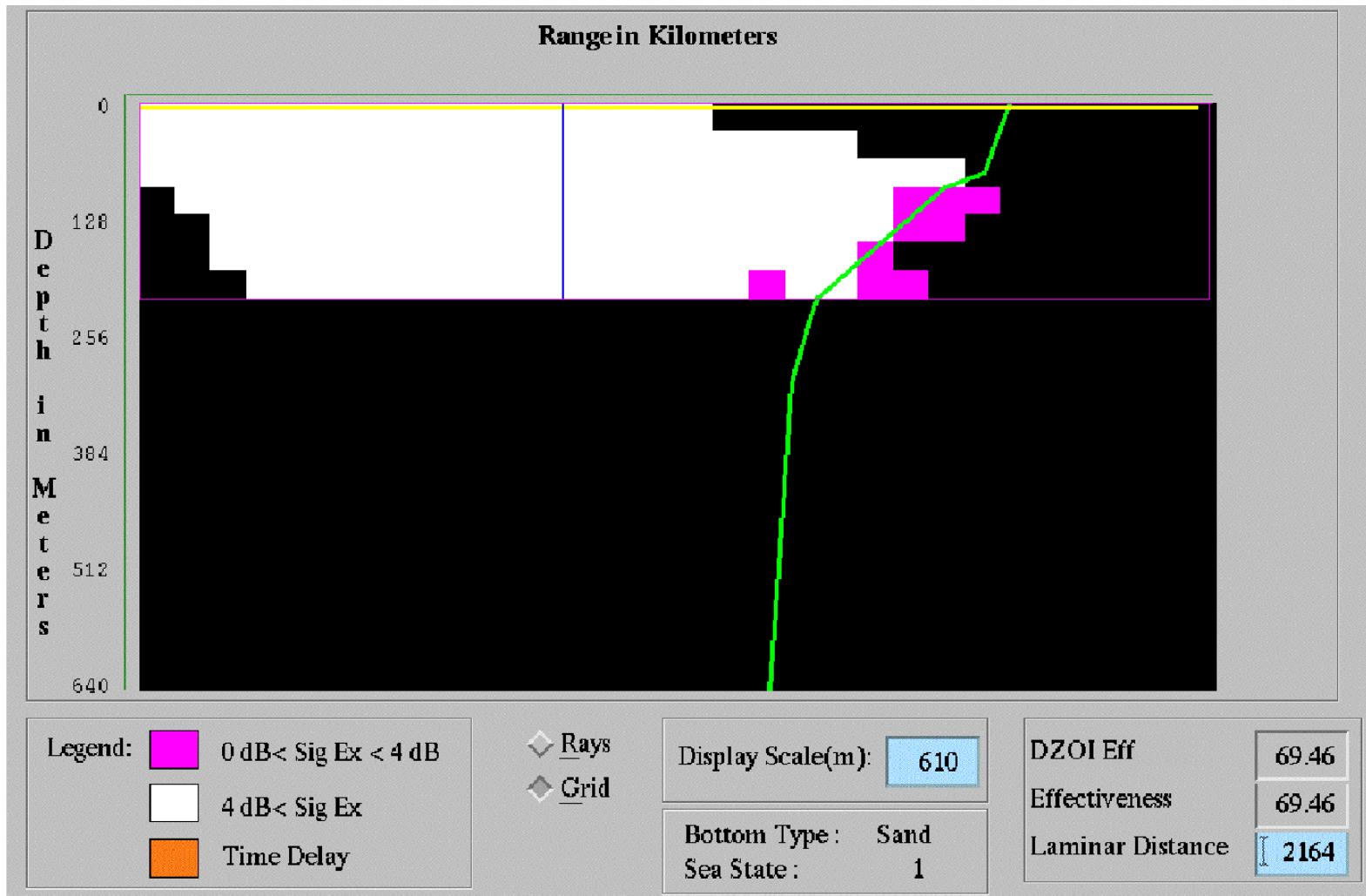
- Listset of search depth/pitch angle/laminar distance/effectiveness
- Listset ranked based on acoustic effectiveness (area coverage) and recommendation made accounting for cavitation and depth separation

SD	PA	LD	EFF
SD 1	PA 1	LD 1	EFF1
SD 2	PA 2	LD 2	EFF2
SD 3	PA 3	LD 3	EFF3
SD 4	PA 4	LD 4	EFF4
SD 5	PA 5	LD 5	EFF5
•	•	•	•
•	•	•	•
•	•	•	•

# Ray Trace Display



# Signal Excess Map



# Generated Output

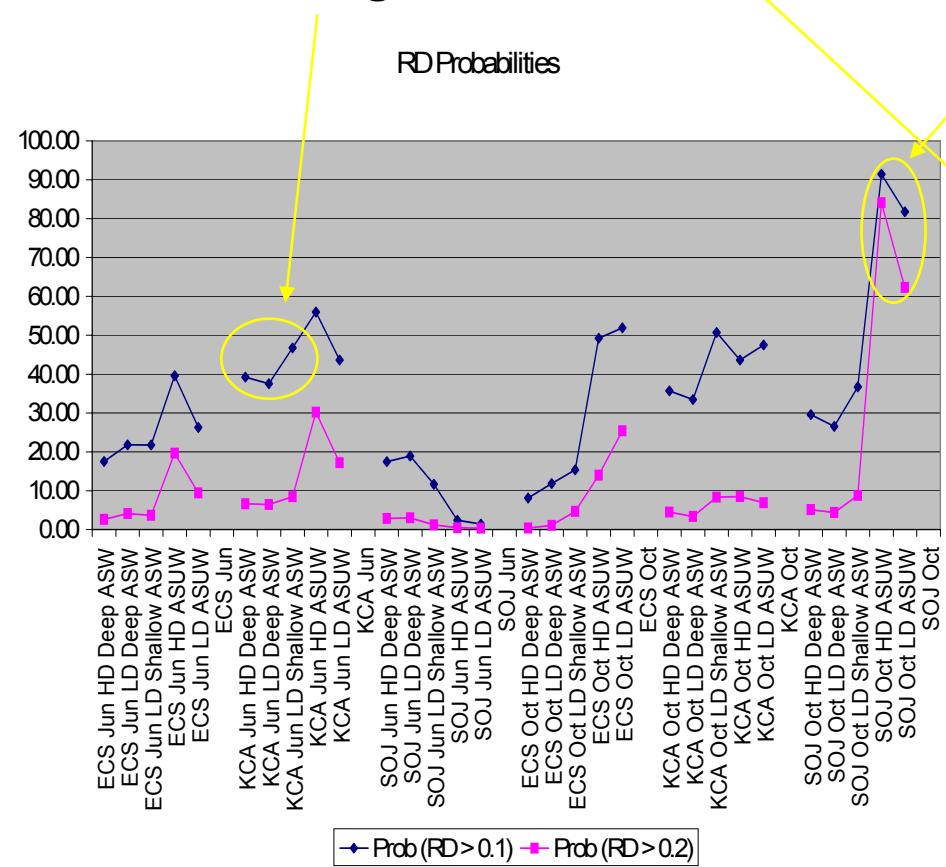
- NUWC routine fed MODAS T,S fields into WAPP
  - grid point by grid point (bypassing EDE)
- 5 tactical scenarios run for each case:
  - ASW with low Doppler, deep target
  - ASW with high Doppler, deep target
  - ASW with low Doppler, shallow target
  - ASUW with low Doppler target
  - ASUW with high Doppler target
- 30 scenarios (6 cases X 5 tactics)
- Presetting process repeated for each grid point in each scenario → over 43,000 listset pairs!

# Analysis of Output

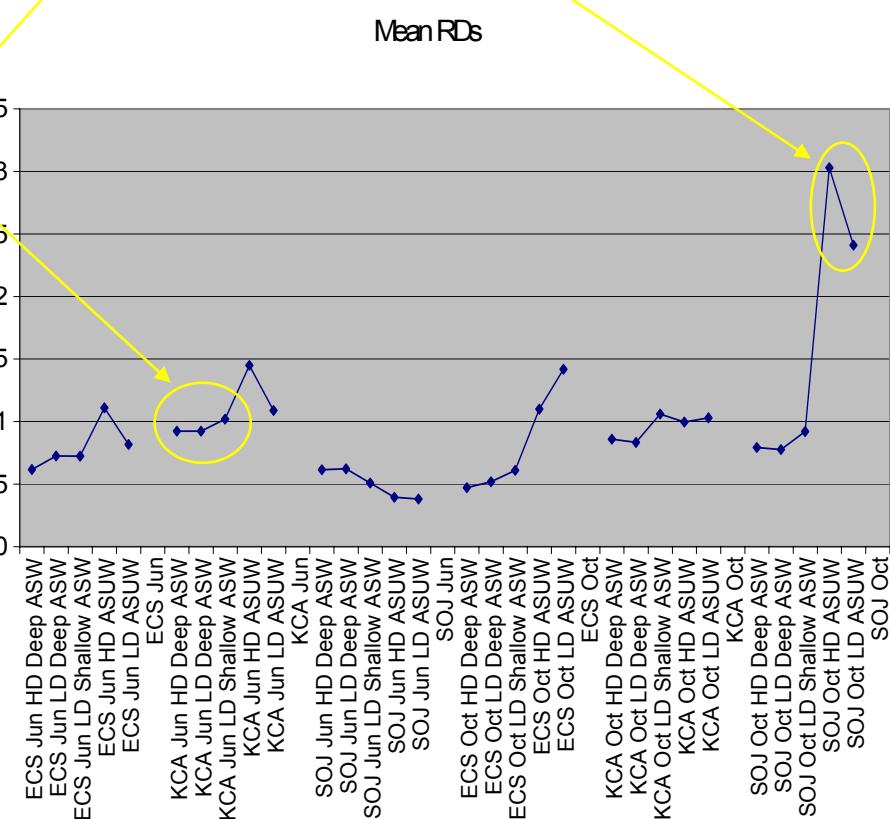
- Used a statistical software package to compare listsets
  - Used relative difference (RD) in area coverage
  - Area coverage (AC)
    - Fraction of the search region with signal excess greater 0 dB (i.e., better than a 50% p(D))
  - $$RD = \frac{|AC_1 - AC_2|}{AC_1}$$
  - Only considered different SD/SA combinations chosen by WAPP
- Generated a histogram for each scenario
  - Shows the number of combinations that fall into set RD ranges
  - Calculated mean RDs,  $\text{Prob}(RD > 0.1)$  and  $\text{Prob}(RD > 0.2)$

# WAPP Output General Stats

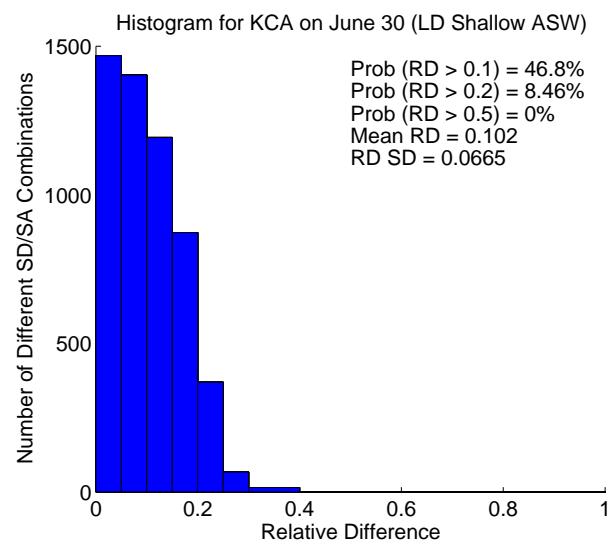
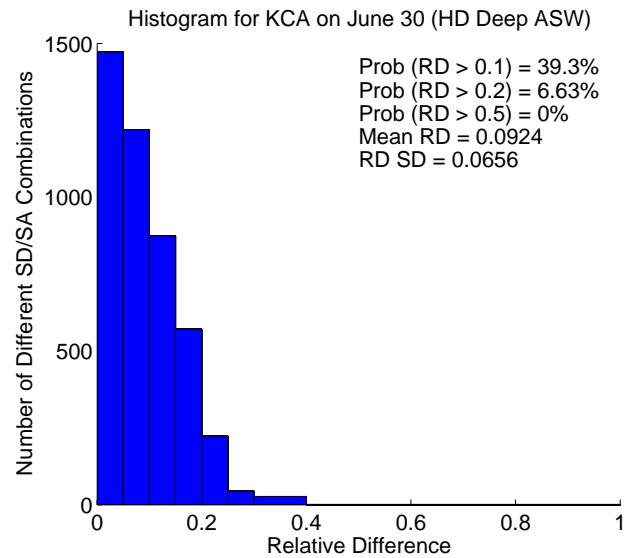
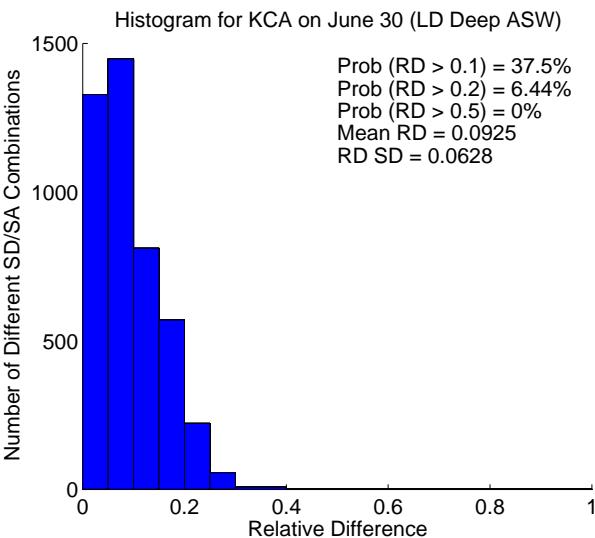
Largest ASW values



Largest ASUW values

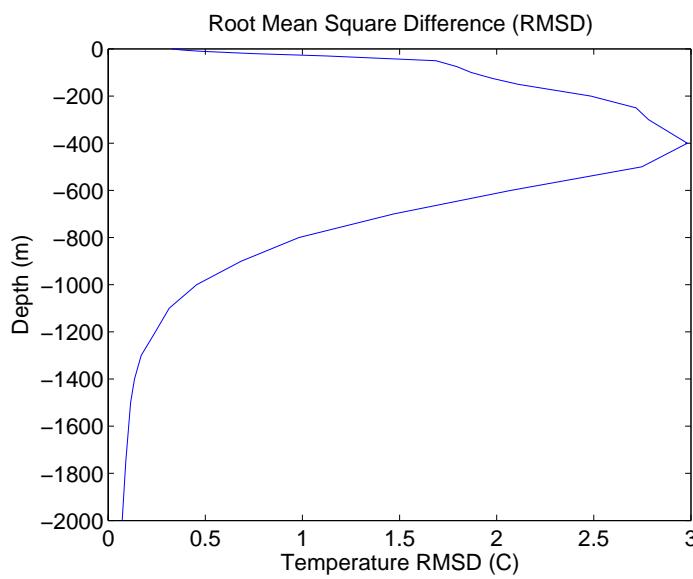
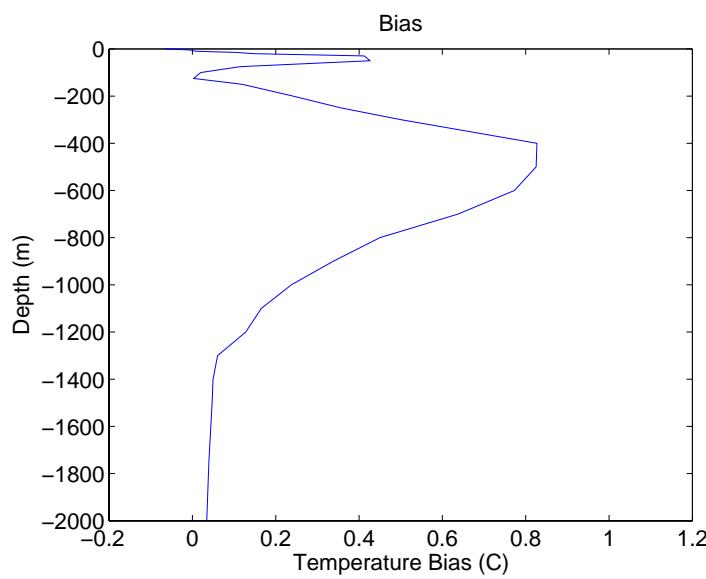
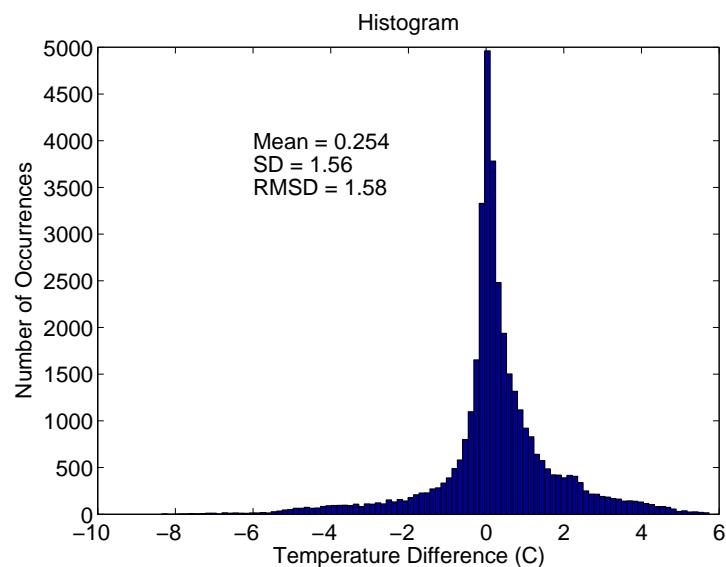
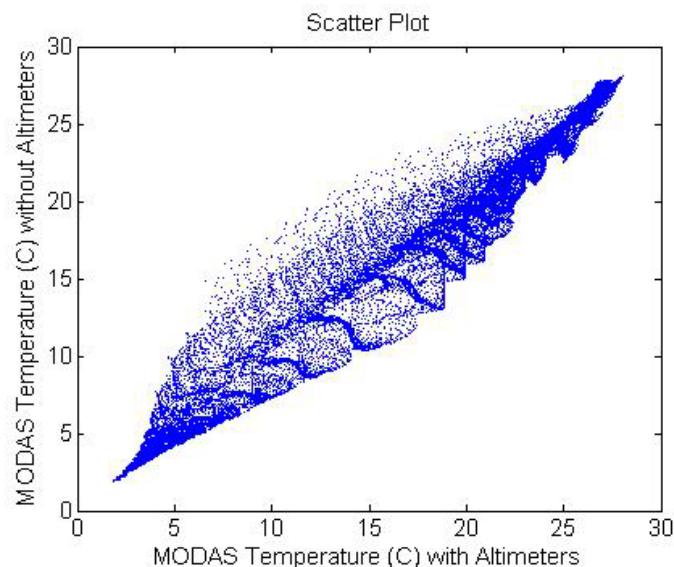


# ASW Histograms for KCA Jun

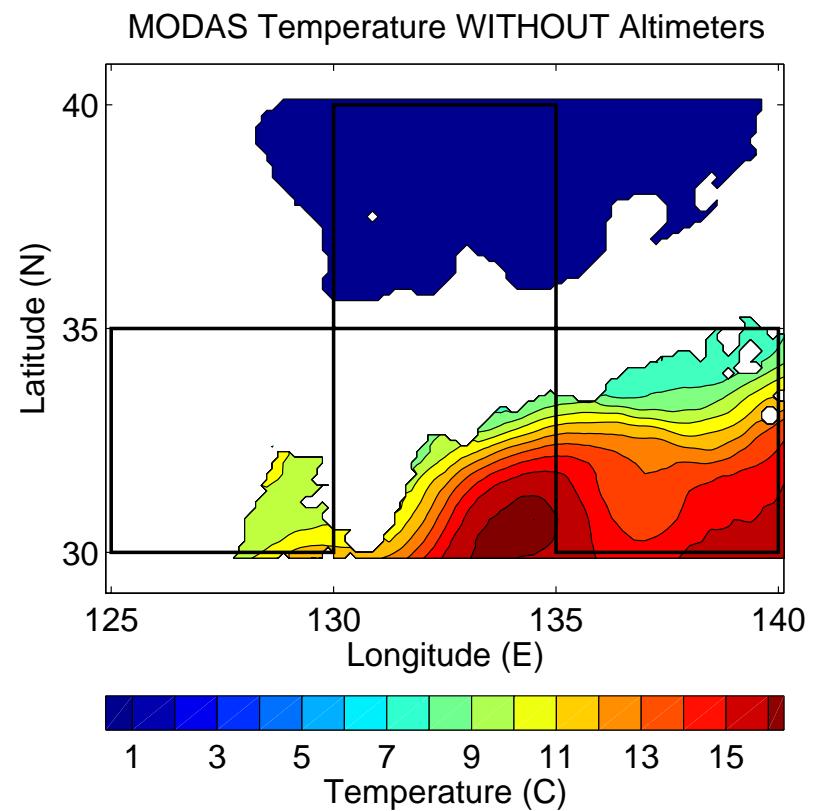
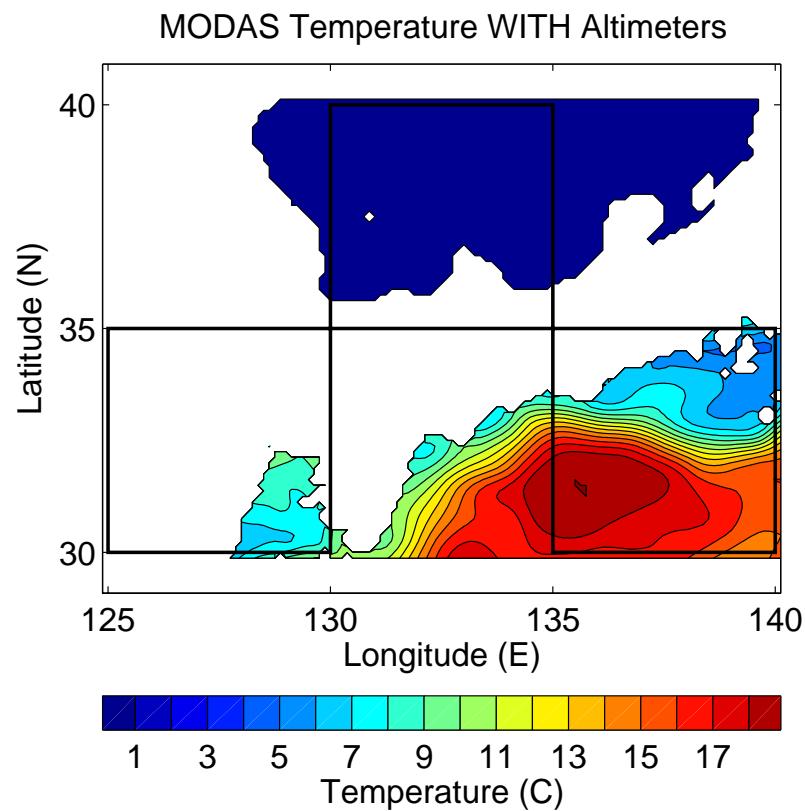


# Temperature Statistics for KCA

Jun 30

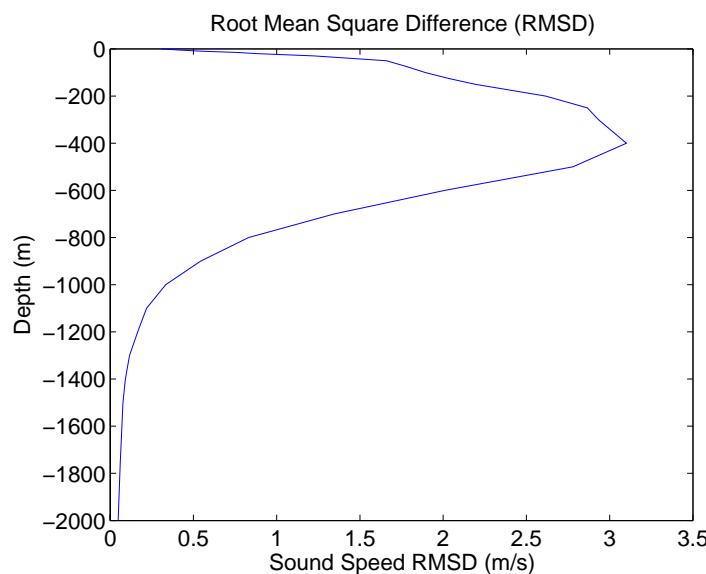
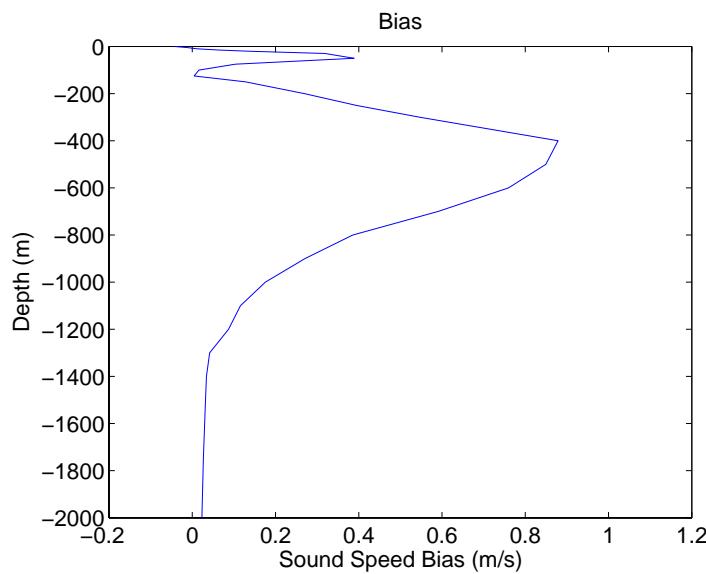
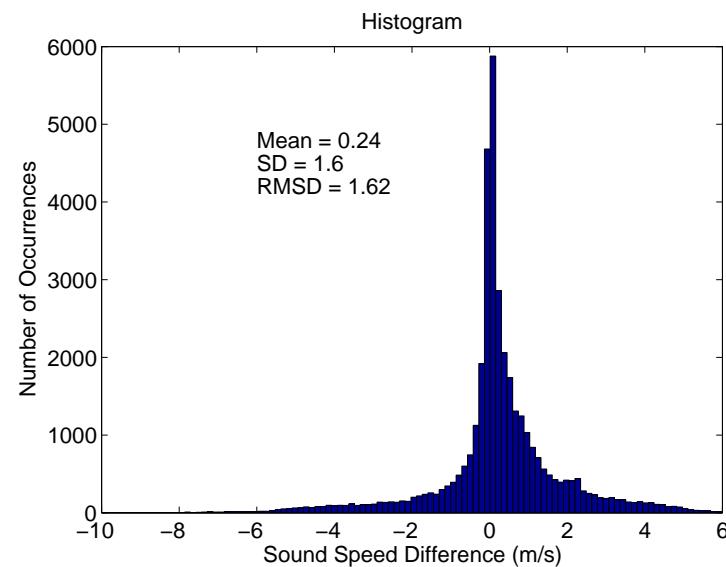
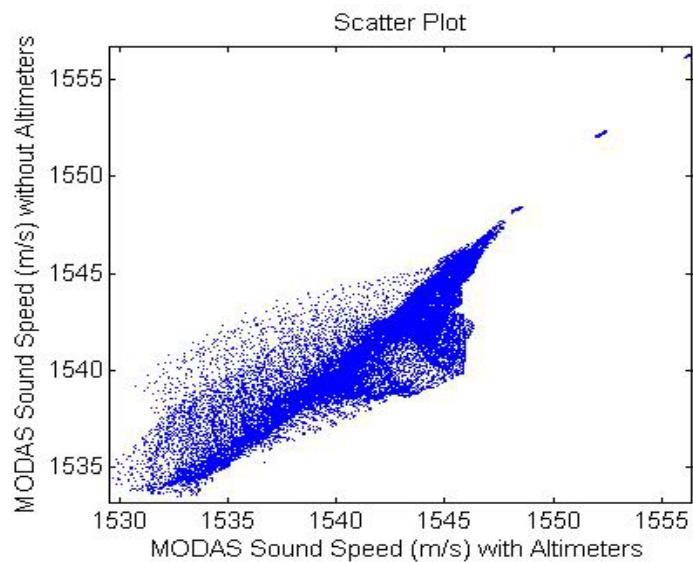


# Comparison of Temperature at 400 m on Jun 30, 2001



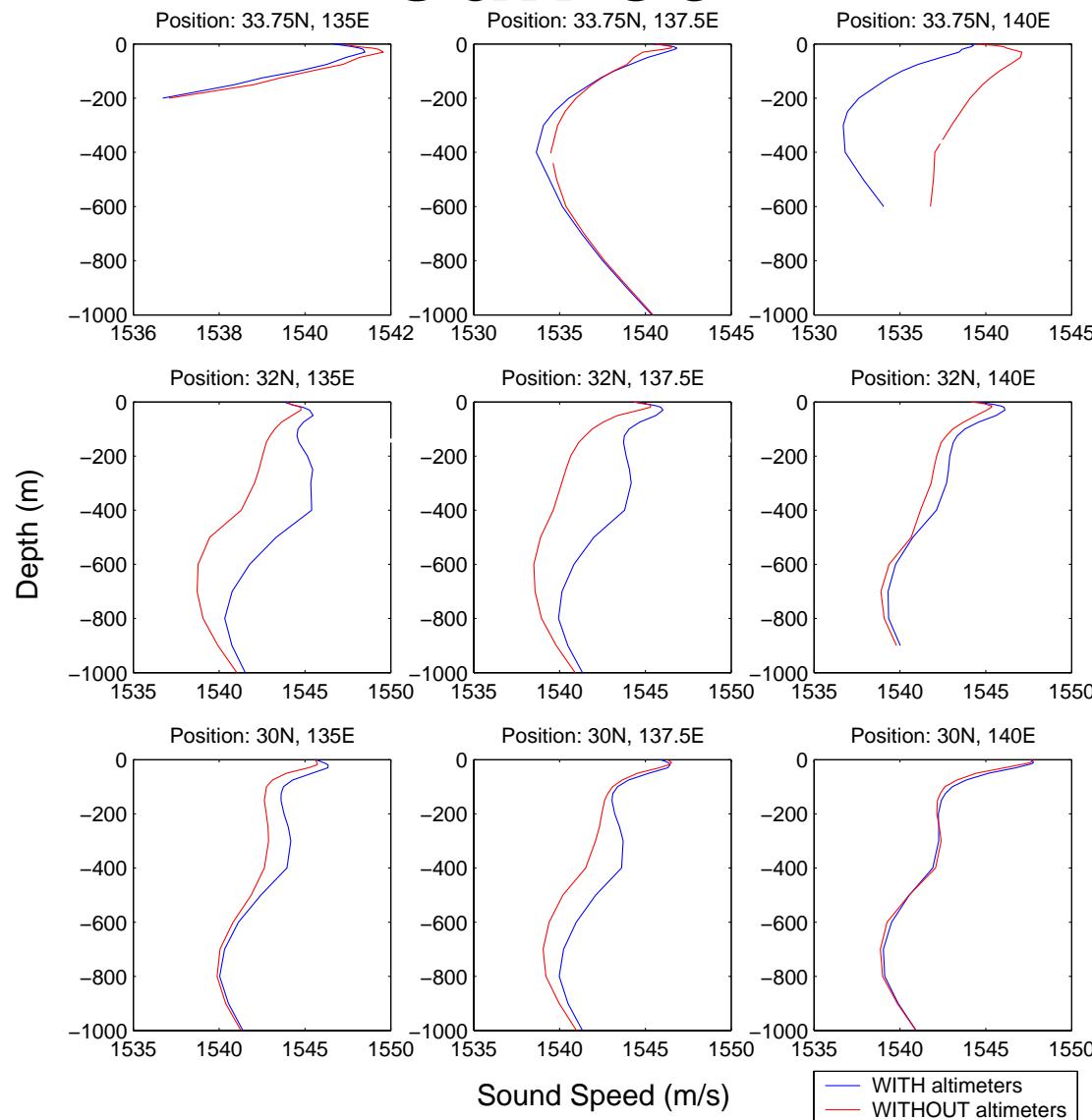
# Sound Speed Statistics for KCA

Jun 30



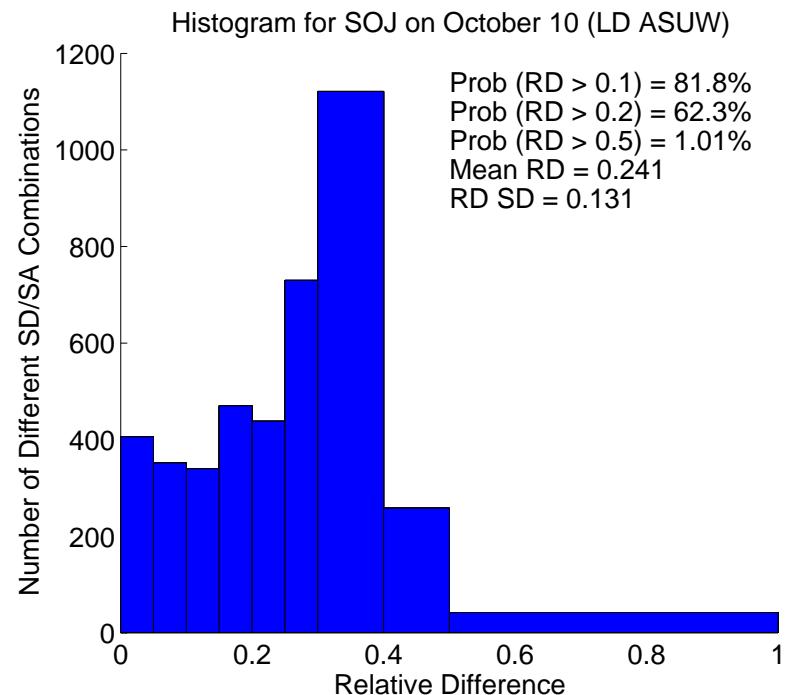
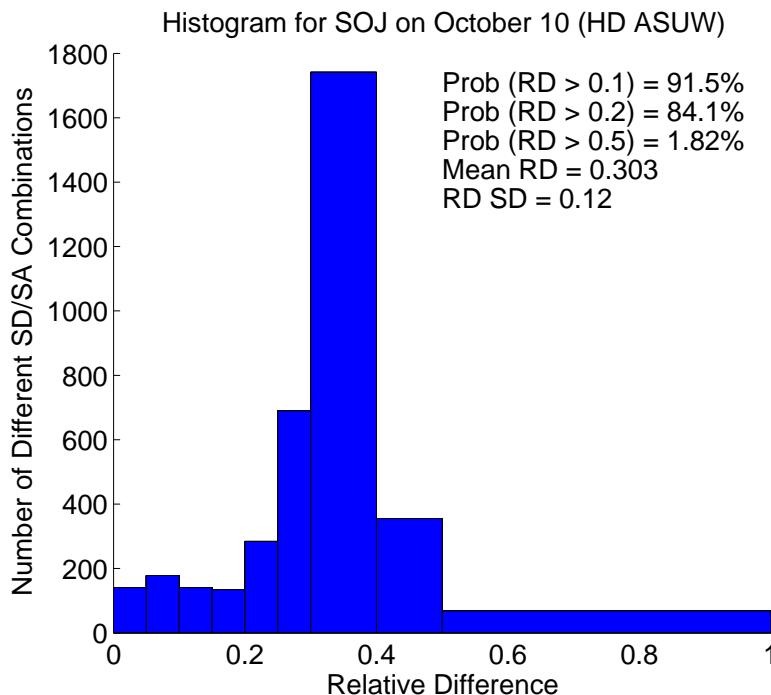
# Sound Speed Profiles for KCA

## Jun 30



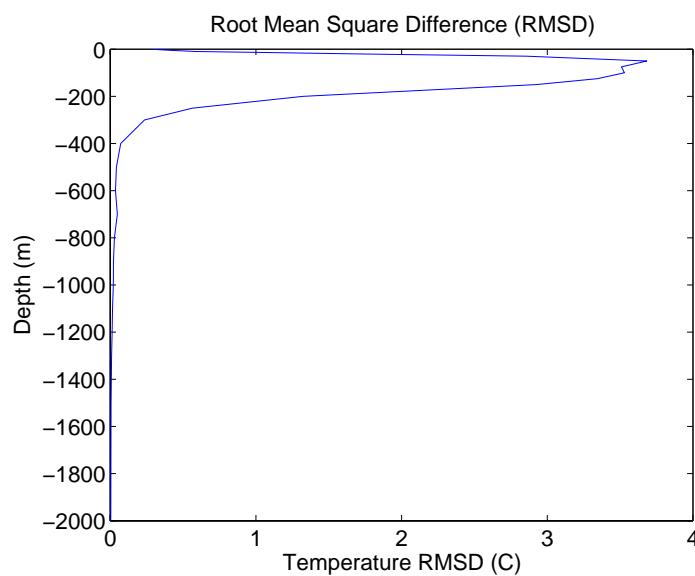
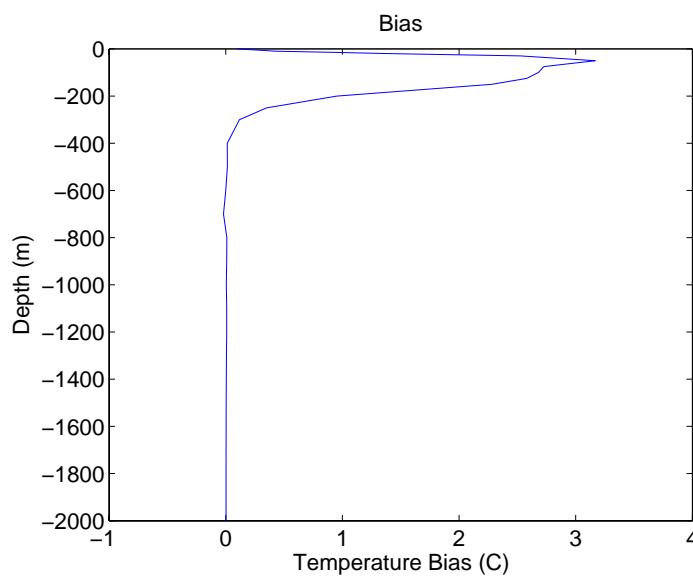
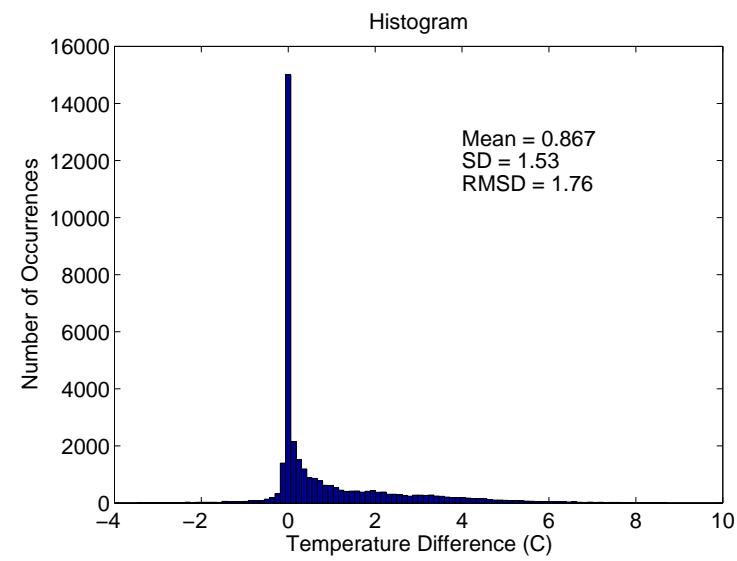
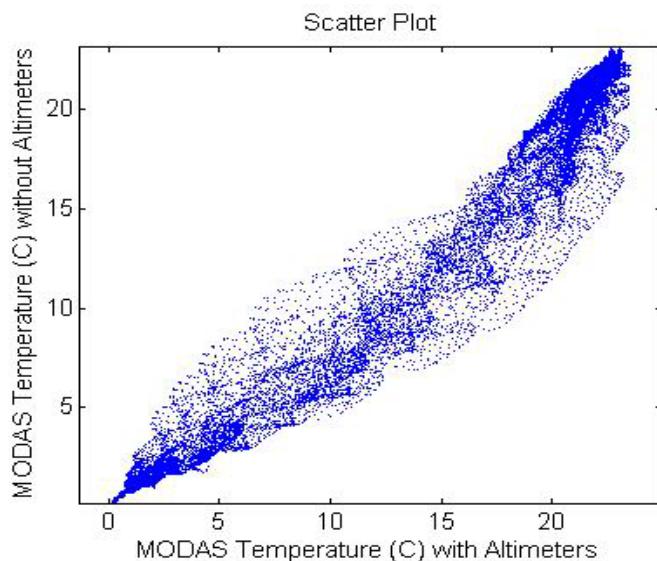
# ASUW Histograms for SOJ

## Oct 10

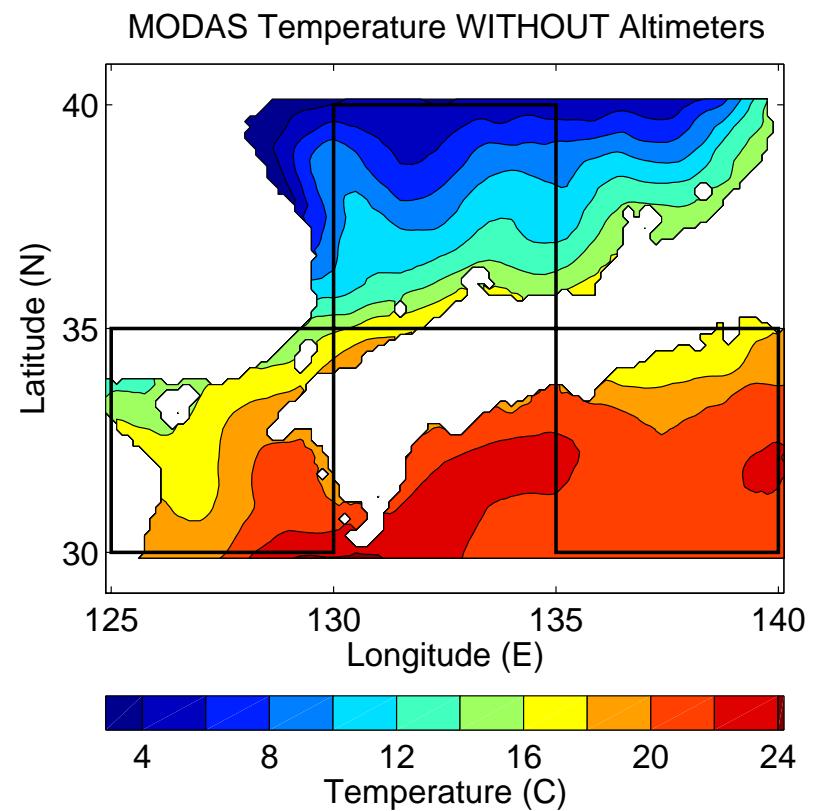
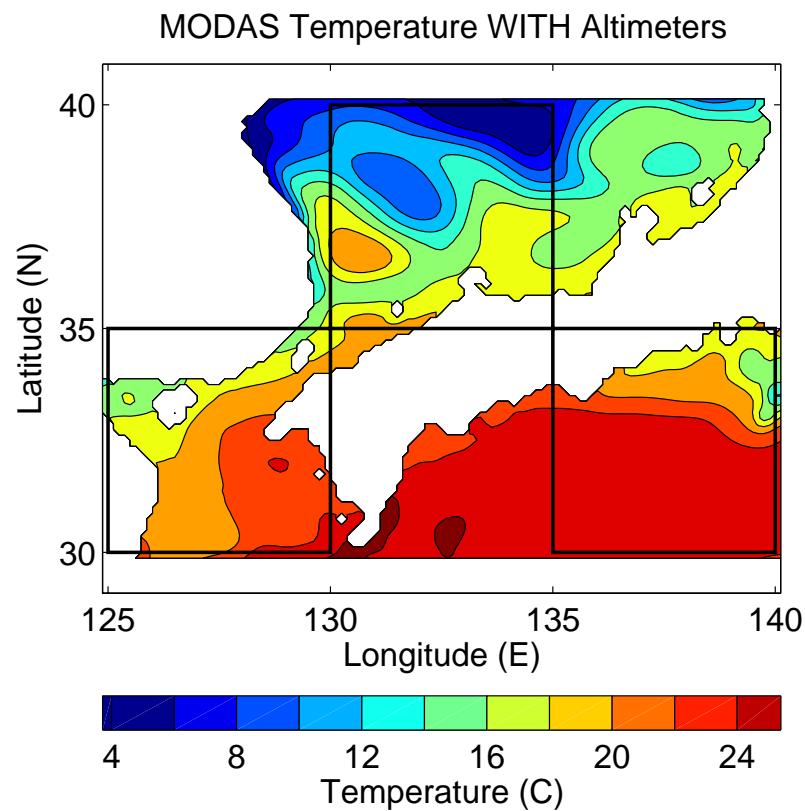


# Temperature Statistics for SOJ

Oct 10

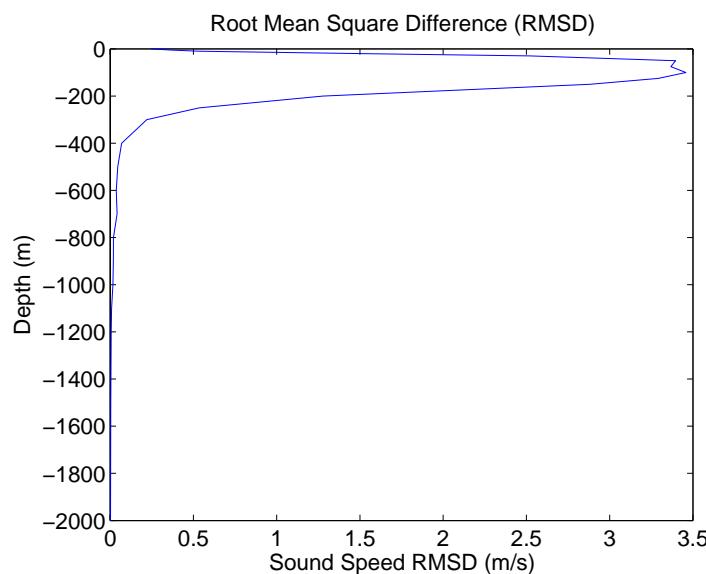
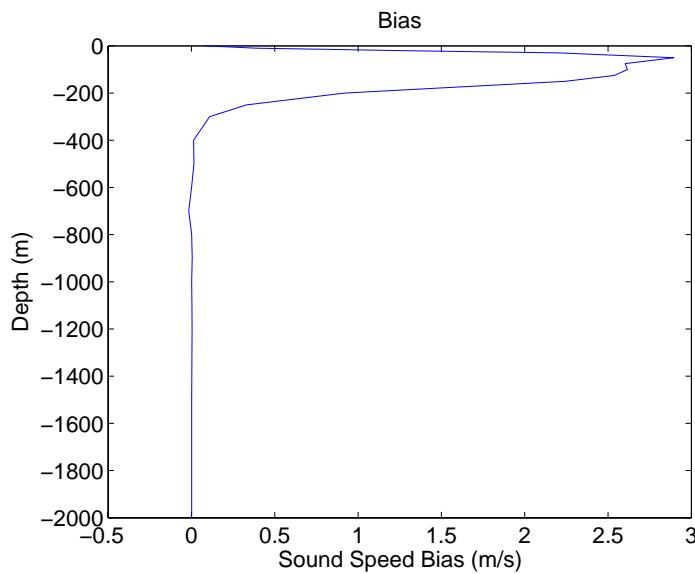
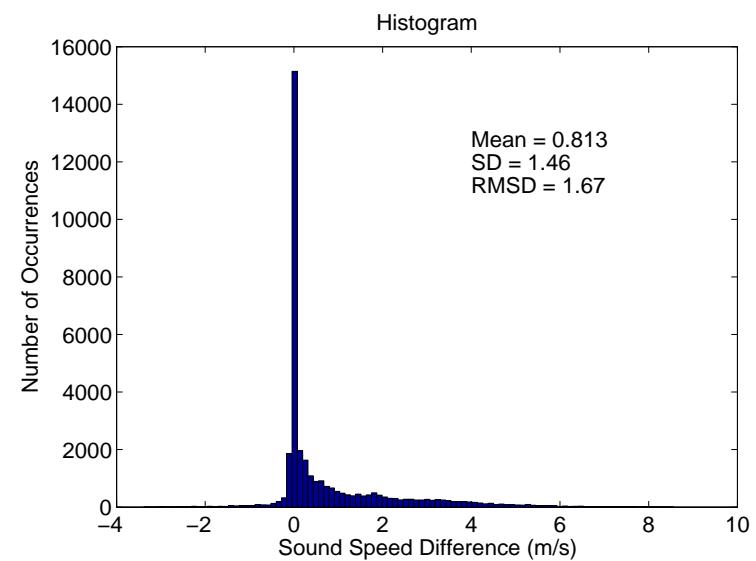
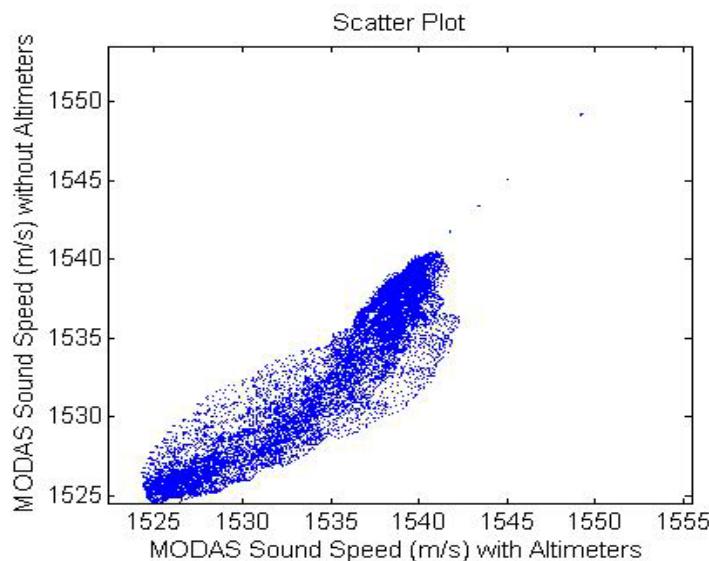


# Comparison of Temperature at 100 m on Oct 10, 2001



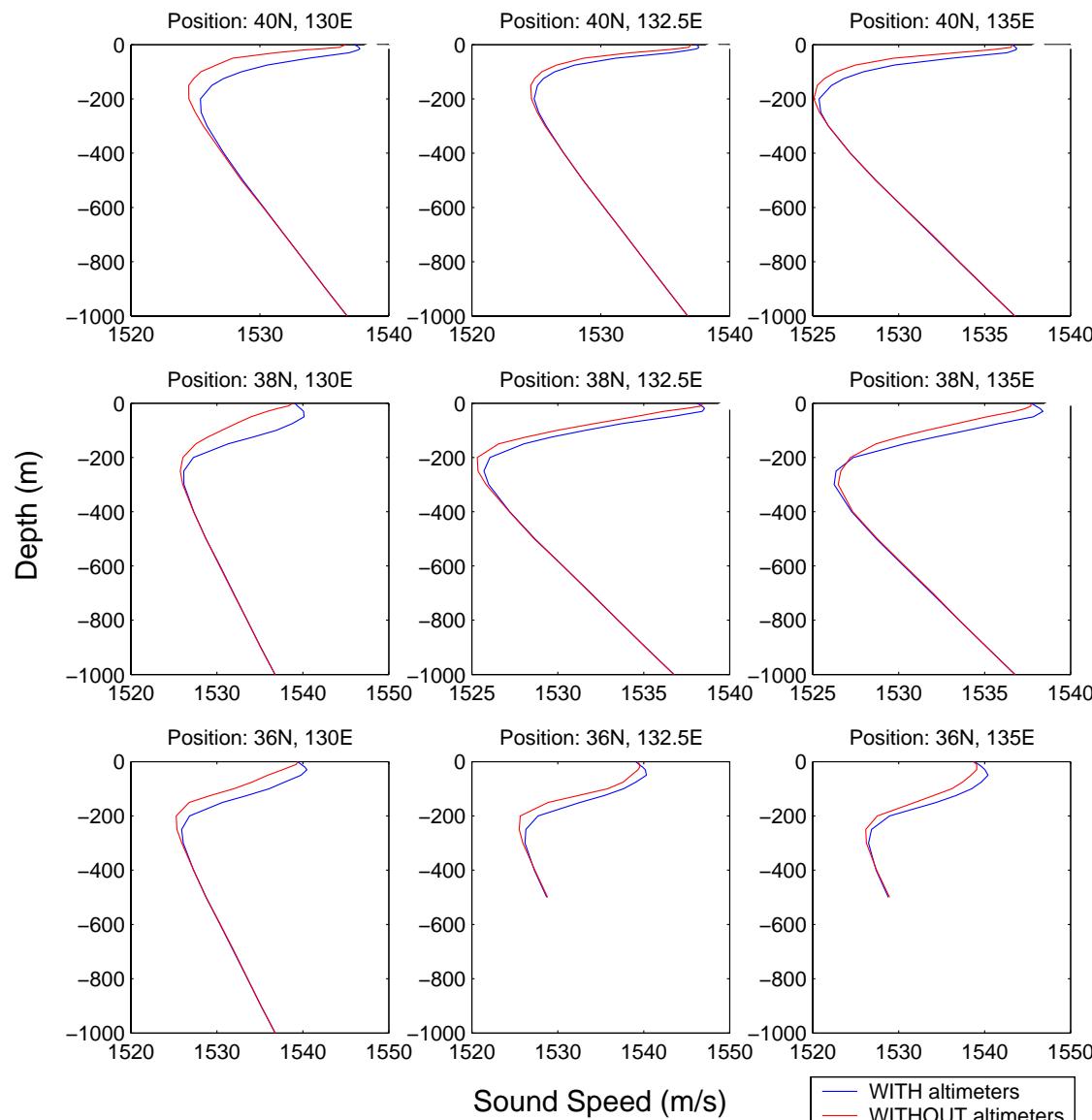
# Sound Speed Statistics for SOJ

Oct 10



# Sound Speed Profiles for SOJ

## Oct 10



# Sensitivity Table

Scenario	Prob(RD>0.1)	Prob(RD>0.2)
ECS Jun HD Deep ASW	17.5	2.6
ECS Jun LD Deep ASW	21.8	4.1
ECS Jun LD Shallow ASW	21.8	3.6
ECS Jun HD ASUW	39.6	19.6
ECS Jun LD ASUW	26.3	9.4
KCA Jun HD Deep ASW	39.3	6.6
KCA Jun LD Deep ASW	37.5	6.4
KCA Jun LD Shallow ASW	46.8	8.5
KCA Jun HD ASUW	56.0	30.2
KCA Jun LD ASUW	43.6	17.2
SOJ Jun HD Deep ASW	17.5	2.9
SOJ Jun LD Deep ASW	18.9	3.0
SOJ Jun LD Shallow ASW	11.6	1.2
SOJ Jun HD ASUW	2.4	0.5
SOJ Jun LD ASUW	1.4	0.3
ECS Oct HD Deep ASW	8.1	0.4
ECS Oct LD Deep ASW	11.8	1.1
ECS Oct LD Shallow ASW	15.4	4.7
ECS Oct HD ASUW	49.2	14.0
ECS Oct LD ASUW	51.9	25.4
KCA Oct HD Deep ASW	35.7	4.5
KCA Oct LD Deep ASW	33.5	3.4
KCA Oct LD Shallow ASW	50.7	8.3
KCA Oct HD ASUW	43.6	8.5
KCA Oct LD ASUW	47.5	6.9
SOJ Oct HD Deep ASW	29.6	5.1
SOJ Oct LD Deep ASW	26.6	4.4
SOJ Oct LD Shallow ASW	36.7	8.8
SOJ Oct HD ASUW	<b>91.5</b>	<b>84.1</b>
SOJ Oct LD ASUW	<b>81.8</b>	<b>62.3</b>

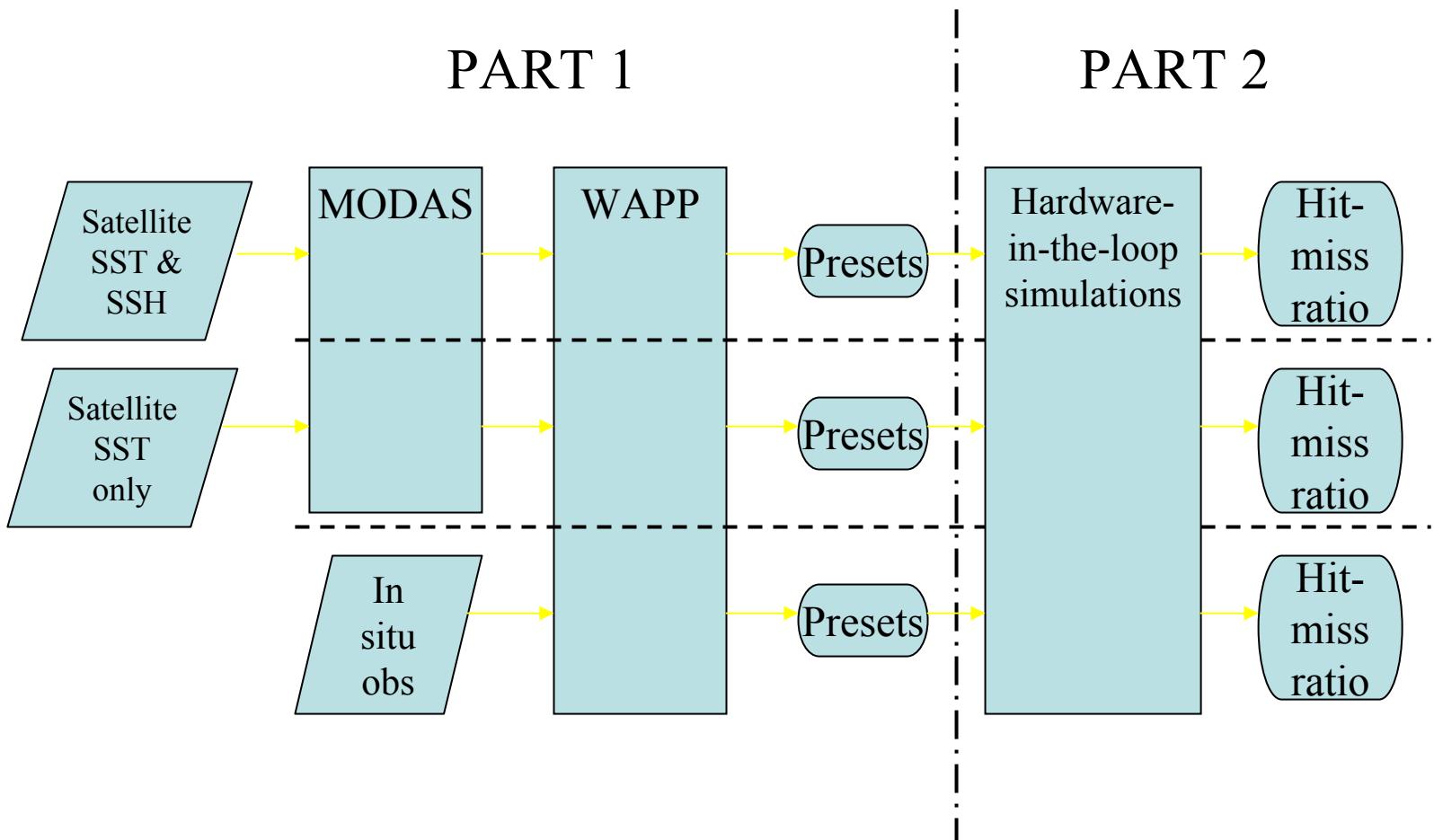
# Conclusions

- WAPP output is sensitive to satellite altimetry data assimilation
  - Especially when MODAS fields differ significantly in the depth zone of interest (due to better depiction of mesoscale features by the field with altimetry)
- Satellite altimeter data contributed as much as an 80-90% chance of having a different engagement outcome
  - Assuming RD of 0.1-0.2 in AC is enough

# Recommendations

- Proceed with the next step
  - Value is related to positive affect on outcome (hit versus miss)
- Perform a study that compares WAPP output using MODAS fields and in situ measurements
  - Ultimate MODAS verification
  - To correlate satellite data value to predicted real world performance
- Perform hardware-in-the-loop simulations
  - To compare hit-miss ratios using presets generated in above experiment for MODAS fields and “reality”
- Vary the number of altimeters assimilated
  - To answer the “how many are required” question

# Recommended Future Work



# **Questions?**